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Dynamic and static sensory methods to study the role of aroma on taste and texture: A multisensory approach to apple perception

Mathilde Charles, Isabella Endrizzi, Eugenio Aprea, Jessica Zambanini, Emanuela Betta, Flavia Gasperi*

Department of Food Quality and Nutrition, Research and Innovation Centre, Fondazione Edmund Mach (FEM), via E. Mach 1, 38010 San Michele all'Adige (TN), Italy

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ABSTRACT

To date very little research has been done on sensory interaction taking into account the temporal component. The objectives of this work were to better understand the influence of aroma perception on taste and texture perception in a real food matrix such as the apple, considering sensory perception both as a static and dynamic process. Another objective was to evaluate the suitability of Temporal Dominance of Sensations (TDS) for studying sensory interaction.

A set of 9 apple samples, made up of apple discs modified with two distinct aromas (3-methylbutyl acetate and (E)-3-hexen-1-ol) and/or two tastants (fructose and DL-malic acid), was used for the experiment. Samples were analysed by Descriptive Analysis (DA) and TDS performed by two different panels. Samples were also analysed using instrumental measurement of texture, sugar and volatile content.

Aroma addition modified perception of the apple in both a static and dynamic way. Some texture-aroma and taste-aroma interaction were highlighted. TDS showed that both aromas made perception of hardness and juiciness less dominant. In some cases, banana aroma modified sweet taste perception and when used without tastants, it tended to anticipate sweetness perception in time. DA evidenced different results: both aromas decreased crunchiness or flouriness intensities when used alone or with fructose respectively. They increased juiciness intensity when combined with malic acid.

TDS confirmed well-known relations between taste and smell and showed its appropriateness for studying sensory interaction. Its combination with DA gathered complementary points of view enriching the analysis and revealing unexpected or time-related interaction, a new perspective for understanding the phenomena linked to perception.

1. Introduction

Flavour is a decisive factor in food acceptability, particularly in the case of apples (Daillant-Spinnler, MacFie, Beyts, & Hedderley, 1996; Harker, Kupferman, Marin, Gunson, & Triggs, 2008). Flavour is also described as one of the most multisensory aspects of our everyday experience. Indeed, its perception brings together different stimuli: aroma, taste, texture and somesthetic sensations, but also sound and visual cues (Spence, 2012). In this study, we focused on aroma, taste and texture, and specifically on aroma-related sensory interaction, to gain insight into flavour perception of the apple.

Fruit aroma is a complex combination of numerous volatile compounds that contribute to the overall sensory quality of fruit specific to species and varieties (Sanz, Olias, & Perez, 1997). More than 300 volatile compounds have been identified in the aroma profile of fresh apples (Nijssen, van Ingen-Visscher, & Donders, 2011). These compounds include alcohols, aldehydes, acids, esters, ketones, terpenoids, sesquiterpenes and ethers (Aprea et al., 2012; Dimick, Hoskin, & Acree, 1983; Ferreira, Perestrelo, Caldeira, & Câmara, 2009; Reis, Rocha, Barros, Delgadillo, & Coimbra, 2009). Two main aroma categories are represented in apple aroma: firstly, the vegetal/herbaceous category, reported with the sensory attributes of green/sharp, cut grass, green apple, cucumber and pumpkin, and secondly, the fruity category made up of the attributes fruity, banana, pear, pineapple, red apple, strawberry and ripe (Aprea et al., 2012; Dixon & Hewett, 2000).

Aroma, taste and texture are perceived through different sensory receptors (olfactory receptors for aroma, gustatory receptors for taste and kinaesthetic and tactile receptors for texture) but can influence each other. Aroma-related sensory interaction has been widely studied and well summarised in review papers

* Corresponding author.
E-mail address: flavia.gasperi@gmail.com (F. Gasperi).

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(Auvray & Spence, 2008; Buettner & Beauchamp, 2010; Delwiche, 2004; Noble, 1996; Poinot, Arvisenet, Ledauphin, Gaillard, & Prost, 2013; Thomas-Danguin, Sinding, Tournier, & Saint-Eve, 2016).

It has been established that perceptions of taste and aroma interact with each other. An odour can have different effects on taste, either by decreasing/masking or by increasing taste intensity, depending on the congruency of the pair of stimuli. For example, caramel aroma masked sourness, whereas it increased sweetness in a sucrose solution (Boakes & Hemberger, 2012). Aroma-texture interaction has also been highlighted, but the underlying mechanisms are still only partly understood. For example, it was demonstrated that either creamy or fatty notes modified texture perception by increasing thickness and creaminess in dairy products (Bult, de Wijk, & Hummel, 2007; Saint-Eve, Kora, & Martin, 2004; Saint-Eve, Lauverjat, Magnan, Déléris, & Souchon, 2009) (See Poinot et al., 2013; for a review).

Furthermore, studies investigating the topic of sensory interaction have generally been performed using model matrices. On the one hand this has the advantage of providing perfect control in terms of composition, but on the other it leads to conclusions based on something other than a real product, and relatively distant from consumer perception (Poinot et al., 2013). To date, very few studies investigating sensory interaction have used real products in general, and more specifically fruit and vegetables. Three works showed interesting applications for sensory interaction research in apple fruit (Charles et al., 2013; Demattè et al., 2014; Poinot et al., 2011), illustrating the feasibility of studies with real food matrices. The authors modified tasting conditions while eating, by modulating either odour with the 'Mouth to Nose Merging System' (Charles et al., 2013), or the sound produced by sample mastication (Demattè et al., 2014) to analyse respectively the impact of orthonasal odour on aroma, taste and texture perception, and the effect of sound on perception of hardness and crunchiness. Poinot and co-workers (2011) employed different masking agents, separately or combined, to study the relative contribution of aroma, taste and texture to overall perception.

Elsewhere, researchers aiming to support fruit breeding research by providing clear targets for enhanced and novel aromas developed a new sensory approach to modify fruit aroma (Altisent, Jaeger, Johnston, & Harker, 2013; Jaeger et al., 2011). They injected essences into pieces of fruit, respectively apples and kiwis, to produce samples with a different aroma, while keeping the texture constant, as an important criterion in consumer perception. The studies demonstrated that the innovative approach was useful for exploring consumers' preferences for new aromas, but could also be applied for other purposes.

Another important element that should be pointed out is that the majority of studies carried out to date have used static methods to investigate such interaction, even though in-mouth perception is a dynamic process. Different mechanisms occur in the mouth while eating or drinking a product, making it change considerably in terms of structure, due to mastication (Aprea, Biasioli, Gasperi, Märk, & van Ruth, 2006), or composition due to salivation (solubilisation of compounds in the saliva, interaction with saliva proteins) and higher temperature (volatilisation of volatile compounds) (Chen & Engelen, 2012). In a review of aroma perception in dairy products, Gierczynski and colleagues (2011) showed that temporal methods have the advantage of providing more accurate descriptions of aroma perception.

When examining the time dimension in sensory science, three main methods need to be considered. The time-intensity (TI) method (Lee & Pangborn, 1986) is a first option. It allows measurement of the intensity of one or several attributes over time. TI was used in some works to study sensory interaction (e.g. (Lethuaut, Weel, Boelrijk, & Brossard, 2004; Ventanas, Puolanne, & Tuorila, 2010; Weel et al., 2002). Nevertheless, by itself the method limits the number of attributes/products that can be assessed in a reasonable time and the "halo dumping" effect cannot be avoided (Clark & Lawless, 1994).

Temporal Check-All-That-Apply (TCATA) is a second option (Castura, Antúnez, Giménez, & Ares, 2016). It was introduced very recently as a new dynamic method for describing multidimensional sensory properties of products as they evolve over time. Assessors are asked to select/deselect among a list of terms the ones they consider applicable to describe the perceived sensations at each moment of the evaluation (Castura et al., 2016). TCATA gives the advantage that several attributes can be evaluated (and selected) at the same time. To the best of the authors' knowledge, this method has not yet been applied to study specifically sensory interaction.

Temporal Dominance of Sensations (TDS) is an alternative option. TDS is a multi-attribute dynamic method developed in the last decade (Pineau, Cordelle, & Schlich, 2003; Pineau et al., 2009; Pineau et al., 2012). It has shown its relevance in describing products during the consumption period and is now frequently used for varied food matrices (Di Monaco, Su, Masi, & Cavella, 2014) but only a few examples have shown applications for the study of sensory interaction. In a previous work, TDS showed its potential to underline aroma-taste interaction during coffee drinking by pairing TDS with *in vivo* nose-space measurement (Charles et al., 2015). Saint Eve et al. (2011) highlighted texture-aroma interaction in model candies, using TDS associated with descriptive analysis.

Together with changes in texture, from more to less consistent, for solid food, flavour perception varies as different taste and olfactory compounds are released (Sudre, Pineau, Loret, & Martin, 2012). During consumption, taste and aroma might evolve from less to more intense perception. Thus, a harder apple would provoke a later taste and aroma perception and/or at a lower intensity. On the contrary, softer apple would favour volatile compound release and lead to more intense and rapid aroma perception (Ting et al., 2012). A juicier apple would promote solubilisation of tastants in saliva with a quicker and stronger taste perception. In this work, different hypotheses were tested based on associations that are commonly found in apple fruit and/or linked to ripening fruit process such as hardness-crunchiness-sour taste-vegetal aroma and juiciness-sweet taste-fruity aroma. The first hypothesis to confirm was that the addition of fruity aroma (e.g. banana) would enhance sweet perception. The second one consisted in verifying that a vegetal aroma (e.g. green grass) would increase sour and hardness/crunchiness perception. As regards to changes related to the time dimension, when the aroma was modified for a given sample, the authors hypothesised that the response time for aroma perception would be shorten. Indeed, with the dipping procedure we used, volatile compounds are forthwith released because they have not been trapped deep in the apple structure. This could also favour an earlier elicitation of sweetness sensation in the case of banana aroma and of sourness sensation in the case of vegetal aroma. TDS as a dynamic method is expected to describe these potential and temporal modifications.

For the reasons cited above, it is important to study flavour considering both multisensory and dynamic points of view. The objective of this study was to investigate aroma-taste and aroma-texture interaction in a dynamic and static way in a real food matrix: apple fruit. This work was also set up to assess whether TDS could be appropriate for studying sensory interaction and gaining understanding of apple flavour perception. By using a dynamic method, this work want to bring to the scientific community an innovative point of view for considering sensory interaction and can be a starting point for understanding underlying phenomena linked to perception which are less known and time-related.

In this study, we used a dynamic sensory method (TDS) as part of an original approach, in addition to both sensory and instrumental static methods, to better understand relations between aroma, taste and texture in a complex and familiar matrix.

Inspired by the study of Altisent et al. (2013), this work proposes a new simple technique for obtaining modified aroma and/or taste in apple fruit pieces, while maintaining an identical texture. Two different compounds naturally present in the apple and corresponding to the two main aroma categories of apple were chosen: 3-methylbutyl acetate, described as banana for the fruity category, and (Z)-3-hexen-1-ol,